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Status and distribution of *Smilosicyopus* species (Teleostei, Gobioidei)

by

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Résumé. – Statut et distribution des espèces du genre *Smilosicyopus* (Teleostei, Gobioidei).

Le statut et la distribution des espèces de *Smilosicyopus* ne sont pas clairs. Durant treize ans, des spécimens ont été collectés dans les îles du Pacifique par le MNHN et des collaborateurs, y compris dans toutes les localités types. Ces spécimens ont été comparés et le gène COI a été séquencé. Sept espèces sur les huit connues ont été validées ; *S. mystax* est considéré comme synonyme de *S. leprurus*. Plusieurs espèces de *Smilosicyopus* ont finalement une répartition plus large que celle qui était supposée initialement et l'endémicité n'est donc pas la règle principale chez ce genre. Une clé de détermination est donnée.

Key words. – Gobiidae – Sicydiinae – *Smilosicyopus* – Distribution.

In the Indo-Pacific areas, river systems are colonised by freshwater gobies with a life cycle adapted to the conditions in these distinctive habitats which are, particularly in islands, young oligotrophic rivers subjected to extreme climatic and hydrological seasonal variations. These species spawn in freshwaters, the free embryos drift downstream to the sea where they undergo a planktonic phase, before returning to rivers to grow and reproduce (Keith, 2003; Keith *et al*., 2006), hence they are called amphidromous (McDowall, 2007). The practical details of their biological cycle and the parameters leading to such evolution in amphidromous gobies are poorly known, but our knowledge increases each year. These gobies contribute most to the diversity of fish communities in the Indo-Pacific insular systems, and have the highest levels of endemism (Keith, 2003; Lord and Keith, 2008; Lord *et al*., 2010; Thuesen *et al*., 2011).

Amphidromous gobies belong mainly to the Sicydiinae subfamily. In contrast to the majority of gobies, sicydiinid pelvic fins are highly modified into a rounded sucking disc. This disk has highly branched pelvic fin rays and thickened pelvic fin spines with a fleshy pad at the distal tip. This strongly effective pelvic suction cup allows them to rapidly access the upper reaches of the catchment area. They are either carnivorous, omnivorous or herbivorous depending on the genus. Dentition is correlated with the feeding behaviour (Keith and Lord, 2011b).

Sicydiinae Bleeker, 1874 comprises nine genera: *Stiphodon* Weber, 1895; *Sicyopus* Gill, 1863; *Smilosicyopus* Watson, 1999; *Lentipes* Günther, 1861; *Cotylopus* Guichenot, 1863; *Sicyopterus* Gill, 1860; *Sicydium* Valenciennes *in* Cuvier & Valenciennes, 1837; *Akihito* Watson, Keith & Marquet, 2007 and *Parasicydium* Risch, 1980 (Keith *et al*., 2005; Keith and Lord, 2011a). Among these genera *Smilosicyopus* was only recently elevated to genus level (Keith *et al*., 2011). According to various authors, *Smilosicyopus* could be the sister group of *Stiphodon* (Keith *et al*., 2011) or of *Cotylopus* (Taillebois, 2012). *Smilosicyopus* is found in clear, high gradient streams with rocky substrate. It lives on the bottom of the river, on top of rocks but it is also often seen swimming in open water in the current between rocks or in large pools (Watson *et al*., 2001; Watson *et al*., 2007; Keith *et al*., 2010b). All known species are carnivorous and possess anteriorly in both jaws slightly recurved conical teeth, needle-like teeth laterally, and between anterior and lateral teeth, at least one (1-3) caniniform tooth, that are well-developed in males (Keith and Lord, 2011b). All *Smilosicyopus* species have been described in the last thirty years, but their status and their real distribution were still unclear, as they are difficult to sample and to distinguish. Taillebois (2012) and Taillebois *et al*. (2012, 2013) published the first knowledge on their life traits, and Taillebois (2012) recently placed *Sicyopus nigriradiatus* in the genus *Smilosicyopus*, increasing to eight the number of described species.

The aim of this note is to clarify the status and the distribution of the all known species of *Smilosicyopus,* that are present in low densities in rivers, often rare and endangered (Larson *et al*., 2012).

METHODS

Indo-Pacific field trips conducted between 1999 and 2012 by the Muséum national d'Histoire naturelle (MNHN) and various collaborations permitted to collect many *Smilosicyopus* (see Watson *et al*., 2001; Keith and Marquet, 2005; Keith *et al*., 2010a, b; Keith and Marquet, 2011; Keith *et al*., 2011; Taillebois, 2012), particularly from all type localities. Species of this genus were collected in Japan, Palau, Micronesia (Pohnpei), Papua, Australia, New Caledonia, Vanuatu (Pentecost, Malekula, Maewo, Gaua, Santo), Salomon, Futuna, Fiji and Marquesas Islands (French Polynesia). More specifically, type localities where specimens were collected included Ryukyu Islands for *Smilosicyopus leprurus* (Sakai & Nakamura, 1979); Marquesas Islands for *Smilosicyopus bitaeniatus* (Maugé, Marquet & Laboute, 1992); Palau for *Smilosicyopus fehlmanni* (Parenti & Maciolek, 1993); Papua (ex-Irian Jaya) for *Smilosicyopus mystax* (Watson & Allen, 1999); New Caledonia for *Smilosicyopus chloe* (Watson, Keith & Marquet, 2001); New Caledonia and Vanuatu for *Smilosicyopus pentecost* (Keith, Lord & Taillebois, 2010); Futuna for *Smilosicyopus sasali* (Keith & Marquet, 2005) and Micronesia (Pohnpei) for *Smilosicyopus nigriradiatus* Parenti & Maciolek, 1993.

All specimens were collected by electrofishing equipment (Portable Dekka 3,000 electric device, Dekka Ltd, Germany) or by snorkelling with a large hand net. Fish were killed with an overdose of clove oil (10%) and stored in 95% ethanol.

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Figure 1. – *Smilosicyopus* species (males). **A**: *S. chloe* (P. Gaucher); **B**: *S. fehlmanni* (P. Keith); **C**: *S. nigriradiatus* (P. Keith); **D**: *S. sasali* (P. Keith); **E**: *S. pentecost* (C. Lord); **F**: *S. bitaeniatus* (E. Vigneux); **G**: *S. leprurus* (P. Keith).

Studied specimens, including type specimens, and morpho-meristic data were detailed in Parenti and Maciolek (1993), Watson *et al*. (2001), Keith and Marquet (2005) and Keith *et al*. (2010a). These descriptions were completed by the additional specimens cited below.

In each type locality sampled, fin clips were taken on a few specimens for DNA extraction and a fragment of the cytochrome oxidase I (COI) gene was sequenced. Methods for DNA extraction and *COI* sequencing are detailed in Taillebois (2012).

Additional specimens (spms)

Smilosicyopus fehlmanni (Parenti & Maciolek, 1993). - MNHN 2013-655, 2 spms: Kokengoné, New Caledonia, Jan. 2010, Keith *et al*. coll. MNHN 2013-654, 1 spm: Kumafa, Papua, 15 Oct. 2010, Keith *et al*. coll. MNHN 2013-658, 1 spm: Brenwé River, Malékula, Vanuatu, Jan. 2010, Keith *et al*. coll.

Smilosicyopus leprurus (Sakai & Nakamura, 1979). - MNHN 2013-656, 1 spm: Kumafa, Papua, 15 Oct. 2010, Keith *et al*. coll. MNHN 2013-660, 2 spms: tourist waterfall, Palau, 2 Mar. 2011, Keith *et al*. coll.

Smilosicyopus pentecost (Keith, Lord & Taillebois, 2010). - MNHN 2013-657, 2 spms: Taveuni, Fiji, 2011, Keith *et al*. coll.

Smilosicyopus nigriradiatus Parenti & Maciolek, 1993. - MNHN 2013-659, 3 spms: Senipehn River, Pohnpei, Micronesia, 12 Mar. 2012, Keith *et al*. coll.

RESULTS & DISCUSSION

A determination key is provided below and table I gives the mean average % of divergence in *COI* between the species. All species are illustrated in figure 1.

Table I. - Mean average % of divergence of COI gene for *Smilosicyopus* species, according to Taillebois (2012).

	S. bitaeniatus	*S. leprurus*	*S. pentecost*	*S. sasali*	*S. fehlmanni*	*S. nigriradiatus*	*S. chloe*
S. bitaeniatus	0.00						
S. leprurus	4.27	0.00					
S. pentecost	4.89	4.59	0.00				
S. sasali	4.73	3.65	3.33	0.00			
S. fehlmanni	4.59	5.23	5.22	4.90	0.00		
S. nigriradiatus	6.32	5.70	5.21	4.89	5.70	0.00	
S. chloe	5.37	4.59	5.37	5.36	5.22	6.81	0.00

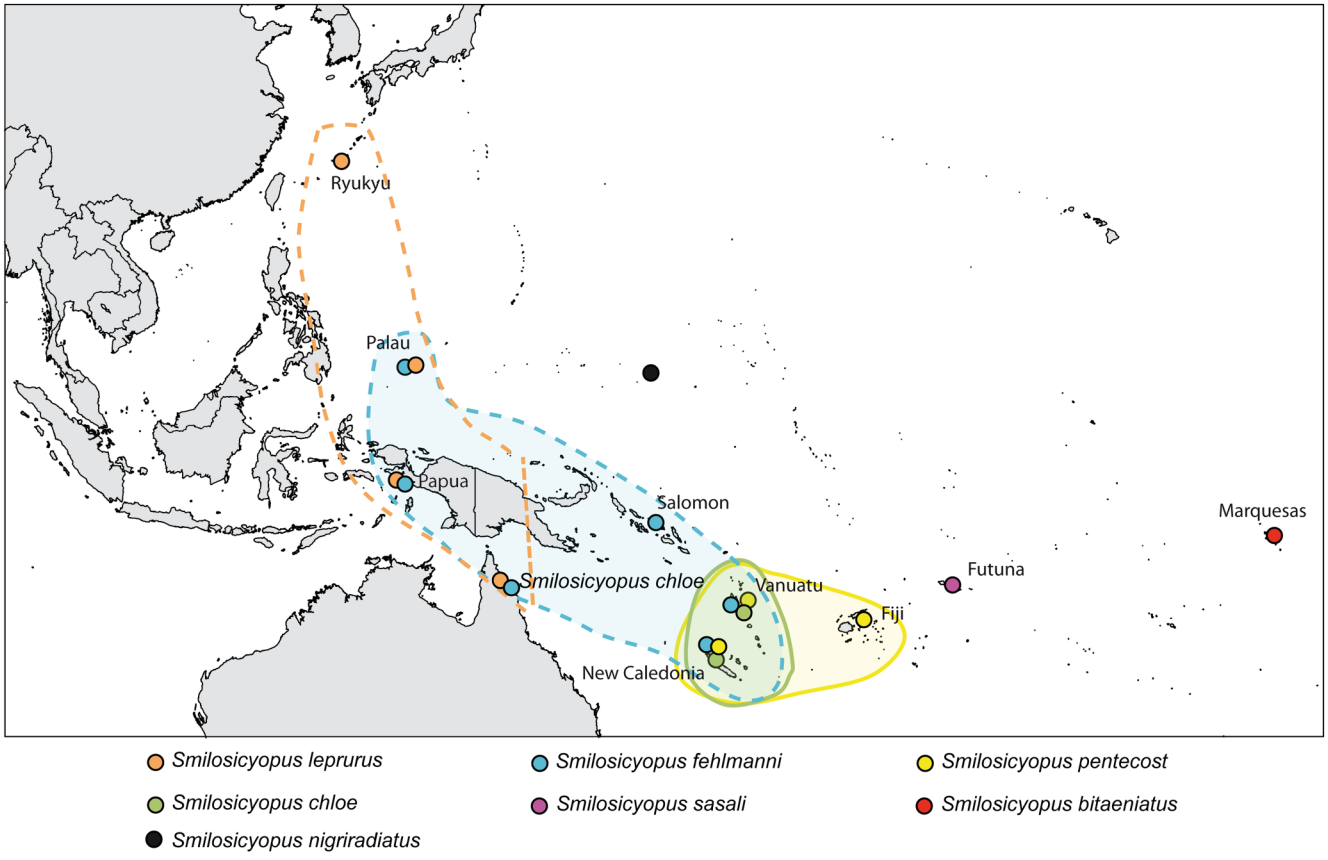

Figure 2. - Distribution of *Smilosicyopus* species.

Our study validates only seven of the eight known species. Indeed, *Smilosicyopus mystax* (Watson & Allen, 1999) seems to be a synonym of *Smilosicyopus leprurus* (Sakai & Nakamura, 1979), as no difference was found in morpho-meristic data nor in genetic distances using *COI* fragment.

Our results further show also that further species of *Smilosicyopus* finally have a broader distribution than initially thought and endemicity seems not to be the main rule, as we found many species outside their supposed range (Fig. 2). *Smilosicyopus fehlmanni,* supposed to be endemic from Palau (Parenti and Maciolek, 1993), is distributed from Palau, Papua Salomon, New Caledonia and Vanuatu; *Smilosicyopus leprurus* supposed to be endemic from Japan (Sakai and Nakamura, 1979) is distributed from Ryukyu Islands to Palau, Australia and Papua; *Smilosicyopus pentecost* is distributed from New Caledonia and Vanuatu to Fiji. On the other hand, the endemicity of *Smilosicyopus bitaeniatus* in Marquesas Islands (Keith *et al.,* 2013), *Smilosicyopus sasali* in Futuna (Keith and Marquet, 2011), *Smilosicyopus chloe* in New Caledonia and Vanuatu (Keith *et al.,* 2010b) and *Smilosicyopus nigriradiatus* in Micronesia are confirmed.

Finally, as far as we know, and although parts of Indonesian islands are still being under prospection, it seems that the biodiversity of *Smilosicyopus* species is higher in the South West Pacific area than in the North West Pacific as previously thought. This brings new insights when studying the evolution of this fascinating group.

Determination key for *Smilosicyopus*

1a. Upper jaw teeth in females and males generally > 21 . . . . . **.2**
1b. Upper jaw teeth in females generally < or = 21; males 13-22 . **.3**

2a. Lateral scales < or = 30; body generally translucent to greyish with a lateral black band from upper pectoral base to caudal fin. . . . . .*S. pentecost* (New Caledonia, Vanuatu, Fiji)
2b. Lateral scales > 30; body generally mottled with black and yellow spots and without a distinct lateral band. . . . . *S. nigriradiatus* (endemic to Micronesia)

3a. Upper surface of head and nape with rows of blackish spots; generally well marked vertical black bands in males . . . . . **.4**
3b. Upper surface of head and nape without rows of blackish spots; no vertical black bands in males . . . . . **.5**

4a. Transverse back series and transverse forward series generally 0, zigzag series 12-17 . . . . . .*S. chloe* (endemic to New Caledonia and Vanuatu)
4b. Transverse back series 0-22, transverse forward series 0-5, zigzag series 9-15. . . . . .*S. fehlmanni* (from Palau, Papua, Salomon to New Caledonia and Vanuatu).

5a. Zigzag series > or = 16; the sixth spiny ray of the first dorsal fin in males is the longest ray and is filamentous . . . . . *S. bitaeniatus* (endemic to Marquesas Islands)
5b. Zigzag series < 16; the fifth spiny ray of the first dorsal fin in males is the longest ray and is not filamentous . . . . . **.6**

6a. Transverse back series 3-13, transverse forward series 0-13, thick moustache from snout to pectoral fin, body with a continued lateral black band from upper pectoral base to caudal fin . . . . . *S. sasali* (endemic to Futuna)
6b. Transverse back series and transverse forward series mainly 0, fine and short moustache above the upper lip, body mainly greyish without a lateral band . . . . . *S. leprurus* (From Japan to Papua).

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REFERENCES

KEITH P., 2003. - Review paper: biology and ecology of amphidromous Gobiidae of the Indo-Pacific and the Caribbean regions. *J. Fish Biol.,* 63: 831-847.

KEITH P. & LORD C., 2011a. - Tropical freshwater gobies: amphidromy as a life cycle. *In:* The biology of gobies (Patzner R.A., Van Tassell J.L., Kovacic M. & Kapoor B.G., eds). Science Publishers Inc, 685 p.

KEITH P. & LORD C., 2011b. - Systematics of Sicydiinae. *In:* The biology of gobies (Patzner R.A., Van Tassell J.L., Kovacic M. & Kapoor B.G., eds). Science Publishers Inc, 685 p.

KEITH P. & MARQUET G., 2005. - *Sicyopus (Smilosicyopus) sasali,* a new species of freshwater goby from Futuna Island (Teleostei: Gobioidei: Sicydiinae). *Cybium*, 29(4): 389-394.

KEITH P. & MARQUET G., 2011. - Wallis and Futuna freshwater fish and crustaceans. 119 p. Paris: SFI ed.

KEITH P., HOAREAU T. & BOSC P., 2005. - A new species of freshwater goby (Pisces: Teleostei: Gobioidei) from Mayotte Island (Comoros) and comments about the genus *Cotylopus* endemic to Indian Ocean. *J. Nat. Hist.,* 39(17): 1395-1405.

KEITH P., LORD C. & VIGNEUX E., 2006. - *In vivo* observations on postlarval development of freshwater gobies and eleotrids from French Polynesia and New Caledonia. *Ichthyol. Explor. Freshw.,* 17: 187-191.

KEITH P., LORD C. & TAILLEBOIS L., 2010a. - *Sicyopus (Smilosicyopus) pentecost,* a new species of freshwater goby from Vanuatu and New Caledonia (Teleostei: Gobioidei: Sicydiinae). *Cybium*, 34(3): 303-310.

KEITH P., MARQUET G., LORD C., KALFATAK D. & VIGNEUX E., 2010b. - Vanuatu freshwater fish and crustaceans. 254 p. Paris: SFI ed.

KEITH P., LORD C., LORION J., WATANABE S., TSUKAMOTO K., CRUAUD C., COULOUX A. & DETTAI A., 2011. - Phylogeny and biogeography of Sicydiinae (Teleostei: Gobioidei) inferred from mitochondrial and nuclear genes. *Mar. Biol.*, 158(2): 311-326.

KEITH P., MARQUET G., GERBEAUX P., LORD C. & VIGNEUX E., 2013. - Polynesian freshwater fish and crustaceans: taxonomy, ecology, biology and management. 282 p. SFI & CEPF ed.

LARSON H., HOESE D. & KEITH P., 2012. - The current status and distribution of freshwater fishes in the Pacific Islands of Oceania. 14 p. IUCN ed., compiled by Pippard H.

LORD C. & KEITH P., 2008. - Threatened fishes of the world: *Sicyopterus sarazini* Weber & De Beaufort (Gobiidae). *Environ. Biol. Fish.,* 83: 169-170.

LORD C., BRUN C., HAUTECOEUR M. & KEITH P., 2010. - Comparison of the duration of the marine larval phase estimated by otolith microstructural analysis of three amphidromous *Sicyopterus* species (Gobiidae: Sicydiinae) from Vanuatu and New Caledonia: insights on endemism. *Ecol. Freshw. Fish*, 19: 26-38.

McDOWALL R.M., 2007. - On amphidromy, a distinct form of diadromy in aquatic organisms. *Fish Fish.,* 8: 1-13.

PARENTI L.R. & MACIOLEK J.A., 1993. - New sicydiine gobies from Ponape and Palau, Micronesia, with comments on systematics of the subfamily Sicydiinae (Teleostei: Gobiidae). *Bull. Mar. Sci.,* 53(3): 945-972.

SAKAI H. & NAKAMURA M., 1979. - Two new species of freshwater gobies (Gobiidae: Sicydiaphiinae) from Ishigaki Island, Japan. *Jpn. J. Ichthyol.,* 26(1): 43-54.

TAILLEBOIS L., 2012. - Endémisme et dispersion chez les Gobiidae Sicydiinae : traits d'histoire de vie et histoire évolutive. PhD Thesis, 236 p. MNHN, Paris, France.

TAILLEBOIS L., MAEDA K., VIGNE S. & KEITH P., 2012. - Pelagic larval duration of three amphidromous Sicydiinae gobies (Teleostei: Gobioidei) including widespread and endemic species. *Ecol. Freshw. Fish*, 21: 552-559.

TAILLEBOIS L., CASTELIN M., LORD C., CHABARRIA R., DETTAI A. & KEITH P., 2013. - New Sicydiinae phylogeny (Teleostei: Gobioidei) inferred from mitochondrial and nuclear genes: insights on systematics and ancestral areas. *Mol. Phylog. Evol.*, in press.

THUESEN P.A., EBNER B.C., LARSON H., KEITH P., SILCOCK R.M., PRINCE J. & RUSSELL D.J., 2011. - Amphidromy links a newly documented fish community of contental Australian streams, to oceanic islands of the West Pacific. *PloS ONE*, 6(10): e26685. doi:10.1371/journal.pone.0026685.

WATSON R.E., KEITH P. & MARQUET G., 2001. - *Sicyopus (Smilosicyopus) chloe,* a new species of freshwater goby from New Caledonia (Teleostei: Gobioidei: Sicydiinae). *Cybium*, 25(1): 41-52.

WATSON R.E., KEITH P. & MARQUET G., 2007. - *Akihito vanuatu*, a new genus and new species of freshwater goby from the South Pacific (Teleostei: Gobioidei: Sicydiinae). *Cybium,* 31(3): 341-349.